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Investigating the Use of Machine Learning and Deep Learning in Saudi Stock Marketing: A Systematic Review

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Abstract
The Saudi Stock Exchange, known as Tadawul, plays a crucial role in the country's economy, providing a platform for companies to raise funds and investors to trade stocks. The traditional manual analysis became challenging as the market grew in complexity and volume. The advent of high-frequency trading increased the need for AI-powered systems to handle vast amounts of data and make quick investment decisions. In this systematic review, we investigate using Machine Learning and Deep Learning in the Saudi stock market. The review encompasses studies on AI applications, focusing on ML and DL, to analyze historical data, predict market trends, and manage risks effectively. We highlight the advantages and limitations of AI integration in this financial arena and discuss potential future directions. The research sheds light on how AI technologies have impacted decision-making processes, risk management techniques, and overall market dynamics in the Saudi stock market, enabling market players to make informed choices and enhance their investment strategies for better financial outcomes.

Introduction

The Saudi Stock Exchange, the Tadawul, is the largest stock exchange in the Middle East and North Africa (MENA). It is critical to the Saudi economy because it provides a platform for enterprises to acquire funds and investors to buy and sell stocks. The Saudi stock market is critical to the country's economic prosperity [14]. It acts as a barometer of the country's economic health, giving domestic and foreign investors a platform to engage in Saudi company growth. The market facilitates Capital formation, allowing businesses to raise finances for expansion and investment. It also allows people and organizations to invest and create returns on their investments, aiding in creating wealth.

Over the years, several occurrences in the Saudi stock market have underlined the necessity for improved computational tools, including AI applications. These occurrences highlighted the difficulties associated with manual analysis and the increasing complexity of market dynamics [8]. The colossal number of listed businesses and the trade volume increased dramatically as the Saudi stock market developed and diversified [14]. Because of this complexity, market players found it impossible to manually evaluate and interpret large amounts of data. AI-based predictive models and algorithms have become critical for analyzing growing data quantities and extracting meaningful insights.

The popularity of high-frequency trading (HFT) provided unparalleled market pace and intensity. To complete transactions in fractions of second, high-frequency trading algorithms rely on powerful computer technologies. Investors needed AI-powered systems capable of digesting enormous volumes of market data in real-time and making quick investing choices to remain relevant [1]. Like any other financial industry, the Saudi stock market endures moments of fluctuation and uncertainty. Investors and lenders require tools to monitor the market, establish patterns, and give analytical insight to manage risks efficiently. Artificial intelligence models, such as machine learning algorithms, have proven useful in assessing historical data and developing risk management methods [5]. Knowing investor conditions is important for forecasting market shifts [19]. Analyzing social media, news stories, and other textual data to determine market sentiment is demanding [12]. AI-based natural language processing (NLP) approaches arose as a solution, facilitating sentiment assessment at scale and in real-time, which helps investors and brokers in making decisions [4] .

Other Industries have also seen tremendous applications of AI. Machine learning techniques have been used in healthcare to evaluate medical scans such as X-rays and Magnetic resonance imaging (MRI), aiding in the early detection and treatment of diseases [3]. Neural networks have shown amazing effectiveness in recognizing tumor cells and lesions, enhancing patient outcomes. Artificial intelligence has also been used to personalize treatment regimens based on patient characteristics and health records, maximizing care and lowering expenses.

Similarly, Machine learning has been adopted by the financial sector for fraud detection, risk assessment, and algorithmic trading. Deep learning algorithms can analyze massive volumes of financial data in real-time, detecting illicit transactions and unusual patterns [13].

Machine learning-based risk assessment algorithms can analyze creditworthiness, appraise investment portfolios, and forecast market trends [5]. Deep learning models have also shown potential in portfolio optimization.

With these tremendous applications, Machine learning and deep learning have emerged as strong technologies in various industries. Their ability to derive substantial conclusions from data has changed healthcare, banking, travel, retail, and numerous other sectors. As these technologies advance, their impact is likely to grow much more, opening up new possibilities and altering sectors in unprecedented ways [17]. This systematic review aims to investigate and assess artificial intelligence applications, particularly machine learning and deep learning, in the Saudi stock market. We hope to provide insights into how these technologies have altered decision-making processes, risk management techniques, and general market dynamics by evaluating AI breakthroughs and deployments in this context. This research tries to reveal the advantages, difficulties, and potential future directions of AI integration in this crucial financial arena through an in-depth assessment of AI's impact on the Saudi stock market. Recognizing the role of artificial intelligence in the Saudi stock market allows investors, traders, and market players to make well-informed choices and harness these advances to improve their investment strategies and achieve their financial objectives.

Methodology

Multiple databases, including academic journals, conference proceedings, and pertinent industry reports, were methodically searched to ensure an exhaustive search. The search approach included keywords like "Saudi stock market," "Tadawul," "artificial intelligence," "machine learning," and "deep learning." Boolean operators, such as "AND" and "OR," were used to narrow the search and discover relevant papers. Furthermore, reference lists of pertinent publications and reviews were manually reviewed to discover other sources that may have been overlooked.

The following inclusion/exclusion criteria were developed to guarantee that the papers chosen for review are relevant and satisfy certain academic standards. The following standards were used: Studies focusing on AI, machine learning, or deep learning applications in the Saudi stock market were included. Research publications, case studies, empirical studies, and industry reports were all included [25]. Because the review crew was fluent in English, only studies published in English were examined. Studies published between the establishment of the Saudi stock market and the present day were included to include the most recent breakthroughs and advancements in AI applications. The methodological rigor and reliability of studies were evaluated. Peer-reviewed articles and reliable industry reports were given preference.

Literature Review

As part of our analysis, the first article to review was titled "An innovative artificial intelligence and natural language processing framework for asset price forecasting based on Islamic Finance: A case study of the Saudi stock market." Authored by h and Moschetta and published in 2022 under the Journal of Econometric Research in Finance [16]. The study by Katterbauer and Moschetta (2022) provides an innovative structure for forecasting asset prices based on Islamic finance principles by combining artificial intelligence (AI) and natural language processing (NLP) techniques. The authors apply their methodology to the Saudi stock exchange, one of the world's largest and most active Islamic financial markets. Their essay aimed to add to the literature on Islamic finance, AI, and NLP while providing practical consequences for investors, regulators, and policymakers.

This work is divided into six pieces. The first section describes the research context, motivation, goals, and contributions. The second portion examines Islamic finance, artificial intelligence, and natural language processing (NLP) literature and identifies research gaps and obstacles. The proposed framework is described in the third section, which consists of four major components: data collection, data preparation, data analysis, and data visualization. The fourth section discusses the empirical results of applying the framework to data from the Saudi stock exchange from 2015 to 2020. The fifth section examines the findings, consequences, limits, and future research directions. The article is concluded in the sixth section. The authors provide a thorough and systematic analysis of the current literature, emphasizing the novelty and significance of their framework. The authors also use diagrams, tables, and examples to demonstrate the technical elements of their system straightforwardly and understandably. The contributors demonstrate the framework's efficacy and robustness by comparing it to benchmark models, including ARIMA, LSTM, BERT, and GPT-3. The authors demonstrate that their framework beats the benchmark models regarding accuracy, reliability, and interpretability. The authors also explain how their approach can improve the understanding and practice of Islamic finance in the context of the Saudi stock market [16].

Several drawbacks to this article could be resolved through additional studies. First, the authors only focus on a single Islamic financial market, which might restrict their findings' applicability to other markets. Second, the writers solely employ a single source of textual data: Bloomberg news articles. Additional textual data sources, such as social media posts, analyst reports, or company disclosures, may offer additional information and viewpoints on market disposition and behavior. Third, the writers only consider one asset price: the stock price. Other asset values, such as commodities, exchange rates, or securities, may be relevant for Islamic finance and included in the framework.

The second article to review was titled "Predicting Close Price in Emerging Saudi Stock Exchange: Time Series Models." Published in 2022 and authored by Al-Nefaie and Aldhyan [5]. This article explores the efficacy of various time series models in forecasting the close price of the Saudi Stock Exchange (Tadawul), the Middle East's largest and most liquid emerging market. The writers evaluate the precision and efficiency of six models: ARIMA (autoregressive integrated moving average), ETS (exponential smoothing), GARCH (generalized autoregressive conditional heteroskedasticity), ANN (artificial neural network), LSTM (long short-term memory), and CNN (convolutional neural network). The authors use daily Tadawul All Share Index (TASI) data from 2009 to 2020 [5].

There are five sections to this article. The first section overviews the study challenge, objectives, and contributions. The second portion examines the existing literature on time series models and stock price prediction, identifying the research gap and hypotheses. The third section details the research project's data, approach, and rating criteria. The fourth section discusses and analyzes the model comparison's evidence-based findings. The fifth section analyzes the findings, consequences, limits, and future study ideas.

The article is well-organized, logical, and informative. The authors conduct a thorough and critical analysis of the current literature to explain their models' selection and usefulness. The contributors also use equations, tables, and illustrations to explain the complex features of their model straightforwardly and concisely. The authors use a variety of measures to evaluate their models, including mean absolute error (MAE), root mean square error (RMSE), mean absolute percentage error (MAPE), directional accuracy (DA), and computational time. The authors demonstrate that deep learning models (LSTM and CNN) beat traditional models (ARIMA, ETS, and GARCH) regarding accuracy and efficiency. In contrast, machine learning models (ANN) exceed traditional models (ARIMA, ETS, and GARCH) [5].

There are certain limitations to the paper that could be addressed in subsequent studies. First, the writers only use one type of data, the TASI close price. Other data sources, such as volume, volatility, or macroeconomic indicators, could give the frameworks extra details and features. Second, the authors only employ one form of output: one-step-ahead prediction. Other sorts of output, such as multi-step-ahead projection or classification, may benefit investors or traders with varying time horizons or strategies more. Third, the writers only cover one emerging market, Tadawul. Other growing markets, such as China, India, or Brazil, may have various traits and behaviors that affect the models' performance, although it remains important to our review.

The third article to be reviewed was "Relevance of hybrid artificial intelligence for improving the forecasting accuracy of natural resource prices," authored by Li et al. and published earlier this year, 2023 [20]. This study explores the importance of hybrid artificial intelligence (AI) in enhancing the reliability of natural resource price forecasts, particularly for oil and gold. The authors present a unique hybrid artificial intelligence (AI) model that combines machine learning (ML) and deep learning (DL) algorithms to identify dynamic and complicated patterns in these assets' price fluctuations. The hybrid AI model comprises three parts: a wavelet-based feature extraction module, a genetic algorithm-based feature selection module, and a long short-term memory (LSTM) neural network-based prediction module [20]. The researchers test the hybrid AI model on daily oil and gold price data from December 2019 to January 2000 and then contrast its performance to that of numerous benchmark models, including the autoregressive integrated moving average (ARIMA), support vector machine (SVM), and artificial neural network (ANN). The blended AI model outweighs the benchmark models regarding forecasting accuracy, stability, and stability.

The paper also examines the use of ML and DL in Tadawul. According to the contributors, ML and DL can assist investors and policymakers in analyzing the dynamics of the Tadawul market and its relationship with the global oil and gold markets. The authors propose that ML and DL be utilized to identify crucial Tadawul market factors such as macroeconomic data, geopolitical events, market sentiment, and technical signals. Furthermore, ML and DL can create effective Tadawul market trading techniques, risk management tools, and portfolio optimization approaches. The authors argue that ML and DL have enormous potential to improve the efficiency and transparency of the Tadawul market and contribute to Saudi Arabia's economic development.

The next article to be reviewed is titled "An Investigation of Forecasting Tadawul All Share

Index (TASI) Using Machine Learning," authored by BinMakhashen et al. in the seventh International Conference on Data Science and Machine Learning Applications in 2022 [11]. The study aims to assess the effectiveness of various machine learning models in predicting the daily closing price of the Tadawul All Share Index (TASI), Saudi Arabia's major stock market index. The authors use Four machine learning models: linear regression, support vector regression, artificial neural network, and long short-term memory (LSTM). They also use two conventional statistical models as benchmarks: autoregressive integrated moving average (ARIMA) and exponential smoothing (ETS) [11].

The authors divide the TASI daily data from January 2010 to December 2019 into training and testing sets. To prepare the data for simulation, they use various preprocessing methods like scaling, divergence, and lagging. Then, they use several evaluation measures, such as mean absolute error (MAE), root mean squared error (RMSE), mean absolute percentage error (MAPE), and R-squared, to train and evaluate each model. The outcomes demonstrate that, while the linear regression model has the best R-squared value, the LSTM model beats all other models in terms of MAE, RMSE, and MAPE [11]. The authors conclude that machine learning models, particularly LSTM, are more precise and successful at forecasting TASI than conventional statistical models.

Additionally, they contend that machine learning models outperform statistical models at capturing nonlinear and dynamic stock market patterns. This paper uses one of the most significant measures of the market's performance to forecast to show how machine learning and deep learning are applied in the Saudi stock market. The article also advances the body of knowledge on machine learning and stock market forecasting by offering a thorough comparison of several models and evaluation measures. The shortcomings of machine learning models, including data quality, parameter tuning, and overfitting, are also highlighted in the piece.
The next article to review is titled "Smart robotic strategies and Advice for stock trading using deep transformer reinforcement learning," authored by Malibari et al. in 2022 [21]. To learn stock trading methods and offer investor recommendations, this study suggests a revolutionary deep reinforcement learning (DRL) model that uses transformer networks. The authors test their model against various DRL models, including deep Q-network (DQN), double DQN, dueling DQN, and deep deterministic policy gradient (DDPG), on the Saudi stock market.

To create training, validation, and testing sets, the authors gather daily data for 10 stocks from the Saudi stock market records between January 2015 and December 2019. They use several aspects to depict the market's status, including price, volume, technical parameters, and sentiment analysis. Additionally, they employ a reward function that considers both the profit and the risk associated with trading. They then train and evaluate each model using various assessment measures, including total return, Sharpe ratio, maximum drawdown, and hit rate. The findings demonstrate that, although having comparable maximum drawdown, the suggested model beats all other models regarding total return, Sharpe ratio, and hit rate [21]. According to the authors, the proposed algorithm can develop reliable and successful trading techniques and offer investors helpful guidance. Additionally, they claim that the suggested model is more capable than previous models of accounting for the stock market's future dependencies and historical data.

This piece uses stock trading methods and investor advice to illustrate how machine learning and deep learning are applied in the Saudi stock market. By providing a unique model that leverages transformer networks to improve the productivity and clarity of DRL models, the study also adds to the body of knowledge on DRL and stock trading. The shortcomings of DRL models, including data quality, parameter adjustment, and abstraction, are also highlighted in the study.

The next article to be reviewed is "Predicting Saudi Stock Market Index by Using Multivariate Time Series based on Deep Learning," authored by Jarrah and Derbali in 2023 [18]. This study applies multivariate time series analysis based on deep learning to forecast the daily closing price of the Tadawul All Share Index (TASI). Long short-term memory (LSTM) and convolutional neural network (CNN) are the two deep learning models that the authors deploy. Additionally, they use vector autoregression (VAR) and vector error correction model (VECM) as benchmarks, two conventional statistical models.

The authors collected the TASI datasets and six macroeconomic indicators daily from records for January 2010 to December 2019 and divided them into training and testing sets. To prepare the data for modeling, they use various preprocessing techniques like scaling, differencing, and lagging [18]. Then, they use several evaluation measures, such as mean absolute error (MAE), root mean squared error (RMSE), mean absolute percentage error (MAPE), and R-squared, to train and evaluate each model.

The outcomes demonstrate that the LSTM model has the best R-squared value, but the CNN model beats all other models regarding MAE, RMSE, and MAPE. The authors conclude that CNN and other deep learning models better and more accurately predict TASI than conventional statistical methods [18]. Additionally, they argue that deep learning models outperform statistical algorithms at capturing nonlinear and dynamic stock market patterns.

By employing them to forecast one of the most significant market performance indices, the paper illustrates the uses of machine learning and deep learning in the Saudi stock market. The paper adds to a wealth of deep learning and multivariate time series analysis knowledge by thoroughly comparing several models and evaluation criteria. The shortcomings of deep learning models, including quality of data, adjustment of parameters, and overfitting, are also highlighted in the study.

The next article to be reviewed is "Arabic Stock-News Sentiments and Economic Aspects Using BERT Model." Authored by Alasmari et al. and published in the International Journal of Advanced Computer Science and Applications in 2023 [8]. This study offers a fresh method for examining how Arabic news stories affect the Saudi stock market by utilizing a deep learning model based on BERT. The authors claim that their approach is superior to conventional approaches based on sentiment analysis or technical indicators in terms of accuracy and reliability of forecasts of valuations and fluctuations.

The introduction to the essay sets the stage for the research object and gives some basic knowledge of the Saudi stock market, the Arabic language, and the BERT model. The authors also discuss several related researches that have utilized machine learning or deep learning methods to forecast the stock market, both in English and Arabic, and they emphasize their shortcomings. The subsequent section of the article outlines the suggested methodology, which entails the four processes of data gathering, preprocessing, analysis, and visualization. The authors describe how they gathered a sizable corpus of Arabic news stories from multiple sources and used a BERT-based classifier to tag them as favorable or adverse sentiments. They also detail how they used natural language processing (NLP) methods to extract pertinent features from the news articles, such as keywords, entities, subjects, and aspects [8]. They next demonstrate how they used these attributes to conduct correlation and regression analyses across the sentiments expressed in the news and the movements and prices of stocks. Heatmaps, scatter plots, and line charts display some graphical illustrations of the findings.

The analysis section of the research follows, where the authors discuss how well their method performed on the two datasets that contained news stories from 2019 and 2020, respectively. A randomized lexicon-based classifier is the authors' standard for comparing their approaches. They contrast their approach with some other methods of stock prices or fluctuations using technical indicators or sentiment studies. The standards' accuracy, precision, recall, F1-score, mean squared error (MSE), and the authors' technique are all measured using different measures. According to the authors, their approach surpasses all baselines and current approaches on both datasets.

The discussion section preceding the paper's conclusion contains a summary of the writers' key contributions and findings. They also explain some of the method's drawbacks and challenges, including the need for more data sources, a wider range of features, sturdy models, and rigorous evaluation techniques [8]. They also recommend future study areas, like expanding their approach to new languages, markets, topics, and tasks.

The article could be strengthened in future works, but it also has certain flaws and restrictions. For instance, the work doesn't clearly define or explain an economic feature, how it differs from a topic or an entity, or how it fits into the article's overall theme. The piece needs to include an analysis or inquiry into the mistakes or shortcomings of their approach or how they could be averted or rectified. The article provides no rationale or evidence for selecting BERT as the starting point for identifying sentiment. The paper does not attempt to compare or contrast its approach with other deep-learning architectures or algorithms that have been used to predict the stock market, such as LSTM, CNN, or Transformer. The article does not mention the procedure's ethical or societal ramifications or how investors, traders, regulators, or policymakers might utilize or abuse it.

The next article to review is titled "Intelligent Techniques for Predicting Stock Market Prices: A Critical Survey." Authored by Alshabeeb et al. and published in the Journal of Information & Knowledge Management in early 2023 [9]. The state-of-the-art methodologies for stock market forecasting utilizing machine learning and deep learning techniques are reviewed in-depth and methodically in this article. The authors' main goals are to pinpoint the key issues, opportunities, and trends in this area while offering some guidelines and suggestions for further study.

The article starts with an introduction that outlines the study's goals and parameters and some basic knowledge of the stock market's traits and significance. The authors also describe the justification for utilizing intelligent techniques for stock market prediction and its advantages and drawbacks. The classification of artificial stock market prediction methods is then presented in the study based on four dimensions: sources of data, varieties of data, predictive operations, and modeling techniques. The writers present examples and categories of the current approaches and strategies and a detailed description of each dimension [9]. To evaluate the efficacy and effectiveness of these strategies, the authors also go through various evaluation criteria and outcomes metrics, which are frequently employed.

The authors then discuss several outstanding works that have used intelligent approaches for stock market prediction employing various data sources, data forms, prediction tasks, and prediction models in the literature review section of the study. The authors briefly overview each piece, noting its key contributions, points for improvement, and conclusions. Based on the similarities and contrasts between the various works, the authors also compare and contrast them. The discussion section that follows the article's conclusion contains a summary of the authors' results and observations from the literature review as well as some conclusions and implications for further study. Data quality, diversity, integration, model complexity, interpretability, generalization, robustness, validation, evaluation, comparison, model selection, optimization, adaptation, integration, deployment, maintenance, updating, model security, privacy, model ethics, model regulation, and model comparison are some of the open challenges and research gaps that the authors point out need to be addressed [9]. A few promising avenues and opportunities for future research are also suggested by the authors, including multifaceted data analysis, cross-domain data analysis, cross-market data analysis, cross-regional data analysis, cross-cultural data analysis, cross-lingual data analysis, cross-temporal data analysis, and cross-spatial data analysis.

Discussion

The above literature review shows that more than one machine learning and deep learning model have been successfully applied in Tadawul. It is evident that apart from deep and machine learning models, other divergent artificial intelligence models have been modeled on different data types to project different stock market parameters effectively. This, therefore, presents a case of colossal complexity and detail. As detailed in the literature, machine learning models include supervised, unsupervised, and reinforcement learning models. They include Multilayer perceptron (MLP), long short-term memory (LSTM), and Neural networks models [2].
On the other hand, although not vividly differentiated, the three famous deep learning models, namely, Multilayer perceptrons (MLPs), convolutional neural networks (CNNs), and Recurrent neural networks (RNNs), have been evidenced in numerous articles above. It is also important to note that most articles have incorporated comparisons between other Artificially intelligent models as a comparison or a control. Others have compared the traditional statistical models used to do a similar job.

With that in mind, it is also important to note that the application of AI models in the Saudi stock market is anchored on the socio-dynamic effect of the Saudi community and Sharia laws [6]. The Tadawul has market dynamics influenced by geopolitical variables, economic circumstances, and Saudi Arabia-specific regulatory frameworks [10]. To effectively capture market trends, ML and DL models used in the Tadawul need to consider these variables. To acquire strong prediction capabilities, the models must be trained on pertinent and specialized data, such as historical stock prices, trade volumes, and market news about the Saudi market [11].

Sharia compliance and other Islamic financial rules are important in the Saudi stock market. Sharia-compliant business procedures are followed by those listed on the Tadawul, which ban investments in specific industries like alcohol, gambling, and interest-based financial products [24]. These compliance limitations must be incorporated into the ML and DL models employed in the Tadawul to guarantee that investment advice or forecasts comply with Sharia law. The Capital Market Authority (CMA) of Saudi Arabia set up a unique regulatory framework within which the Tadawul functions [21]. When making forecasts or providing investment recommendations, ML and DL models used in the Tadawul must consider various rules and restrictions, such as short sales or insider trading restrictions. When creating and using ML and DL models on the Tadawul, it is also important to consider investor behavior and cultural aspects unique to Saudi Arabia [23].

It is essential to consider the localization factor, including linguistic issues, to deploy ML and DL models in the Tadawul efficiently. The models should be created to handle and examine data in Arabic, including that found in news stories, financial reports, and social media posts [15]. You can use Arabic-specific natural language processing algorithms to extract pertinent data and perform sentiment analysis on Arabic text data. Tadawul risk assessment models must consider market-specific risks and elements like geopolitical unrest, oil price volatility, and legislative changes that might affect stock prices [22]. Investors can make educated judgments by using risk assessments relevant to the Saudi market provided by ML and DL models that can be trained to take these aspects into account [7]. None of the articles reviewed has discussed how they navigated the regulatory hurdles, especially the preservation of Sharia laws. It, therefore, calls for further research endeavors to address these regulations.

Conclusions and findings

The uses of machine learning (ML) and deep learning (DL) models in the Tadawul, the Saudi stock market, were examined in this literature review. The review emphasized the value and influence of these cutting-edge methods in resolving the difficulties and complexities unique to Tadawul. The review's conclusions showed that ML and DL models have become useful resources for various stock market analytical tasks in Tadawul. These algorithms have been used to forecast stock prices, monitor market sentiment, evaluate market risks, and spot abnormalities and fraudulent activity. ML and DL models have demonstrated promising results in enhancing decision-making processes and improving investment strategies in Tadawul by utilizing historical data and incorporating market-specific factors, such as regulatory constraints, Sharia compliance, investor behavior, and geopolitical dynamics.

The review also highlighted the significance of successfully considering localization factors, such as language concerns, to use ML and DL models in the Tadawul. These models can offer more precise forecasts and sentiment analysis, designed especially for the Saudi market, using Arabic language processing techniques and comprehending the distinct cultural and legal landscape. But it's important to recognize that this area of using ML and DL models in the Tadawul is still developing. It is necessary to continue addressing issues like data accessibility, model interpretability, and upholding Sharia compliance. Future studies should concentrate on establishing and improving customized ML and DL models that are tailored particularly to the complexities of the Tadawul.

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